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MICROWAVE DRYING OF CERAMIC CASTINGS

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Drying of ceramic castings using microwave power was investigated with samples supplied by a major Ontario manufacturer. A pulsed microwave power output of 800 watts for approximately 3 minutes is required to dry the production-sized castings. Each pulse is 1 minute on and 1/2 minute off. Based on the laboratory results, a 12-kW microwave unit is needed to meet the client's required throughput of 5 castings per minute.

At the request of Mr. Jack Brown from Central Region, the use of microwaves to accelerate drying of ceramic castings was investigated for a major Ontario manufacturer. The ceramic castings are used to make various bathroom fixtures, such as soap dishes, toilet paper and toothbrush holders. In the manufacturing plant, drying of the castings usually takes 24 hours at room temperature. The objective of this investigation was to determine the size and operation of a microwave system that could be used to automate the drying process.

SLIP CASTING PROCESS

A mixture of clay and water is used to form a "slip" which is poured into a mould. After an appropriate length of time, the contents are drained and the mould is removed. The resultant clay body, known as a "green body", is left to dry at room temperature for 24 hours. After drying, the castings are glazed and fired to produce the finished products.

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Besides the drying of castings, the manufacturer expressed interest in the use of microwaves for acceleration of slip setting and in-mould drying of the castings. Eventually, it is hoped that the manufacturing process can be fully automated.

TEST PROCEDURE

Samples of ceramic castings (ie, green bodies) were obtained from the plant. After obtaining samples in the morning, microwave drying tests were performed in the industrial electroheat laboratory using the 2450-MHz industrial microwave oven. Sample mass was measured before and after each test, along with the energy consumption and microwave power output levels. After drying, the samples were immediately shipped back to the plant for glazing and firing. The finished samples were examined the following day.

TEST RESULTS

Table 1 shows the test results for two different modes of operation. The continuous mode of operation uses a fixed power level while the pulsed mode cycles the power on for 1 minute and off for 1/2 minute.

DISCUSSION OF RESULTS

The results in Table 1 show that output power level for microwave drying is very important. For example, a continuous microwave output power level of 600 W caused cracking of some samples. However, at lower output power levels, no cracking was observed. This is probably due to the reduced internal vapour pressure build-up. Similar observations were noted with the pulsed power output. It should be noted that, by pulsing, microwave powers above 600 watts can be used without product damage. In addition, this pulsed operation can significantly reduce test duration. The test results indicate that the optimum microwave output power is about 800 W for each casting. This power needs to be pulsed for three cycles (ie, 1 minute on and 1/2 minute off per cycle).

TABLE 1

MICROWAVE DRYING OF CERAMIC CASTINGS

Output Power Level (W)	Mode of Operation	Number of Cycles*	Duration of Test (min)	Initial Mass (kg)	Final Mass (kg)	Comment
400	Continuous		12	708.1	659.8	
500	Continuous		10	658.6	609.2	
550	Continuous		10	693.2	630.7	
600	Continuous		8	687.5	635.8	
600	Continuous		8	717.4	666.8	
600	Continuous		8	684.4	627.1	Sample Cracked
600	Continuous		9	683.4	645.8	Sample Cracked
800	Pulsed	3	4	774.0	748.8	
800	Pulsed	2	2.5	782.6	767.2	
800	Pulsed	2	2.5	834.4	818.6	
800	Pulsed	3	4.0	834.2	808.3	
900	Pulsed	3	4.0	820.1	774.6	Sample Cracked
900	Pulsed	2	2.5	773.8	751.9	Sample Cracked

*Each cycle consists of 1 minute on and 1/2 minute off.

SIZING OF MICROWAVE UNIT

Based on the laboratory results, a 12-kW microwave unit is needed to process the client's required throughput of 5 castings per minute. The details of the calculation are shown in the appendix.

CONCLUSIONS

1. A 12-kW microwave unit is needed to meet the required throughput of 5 castings per minute.

2. Faster drying of ceramic castings can be achieved by pulsing microwave power, rather than by applying it continuously.

3. The optimum microwave output power is about 800 W for each casting. This power needs to be pulsed for three cycles (ie, 1 minute on and 1/2 minute off per cycle).

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APPENDIX

SIZING OF MICROWAVE UNIT

The following section illustrates the steps required to approximate the size of microwave equipment for the drying application.

a) Microwave Unit Size =

Required Throughput x Total Duration of Microwave Energy x Microwave Output Power Level per Casting

$$= \frac{5 \text{ Pieces}}{\text{Minute}} \times 3 \text{ Minutes} \times 800 \text{ W}$$

This value corresponds very closely with the value obtained through calculation of theoretical energy needed to evaporate the water. The alternate method of sizing the unit is illustrated as follows:

Theoretical energy to evaporate the water in one ceramic casting = Q

$$= M_1 \times Cp,w \times (100 - T) + M_1 \times Lv + M_2 \times Cp,c \times (100 - T)$$

where T is the ambient temperature (°C)

M_1 is the mass of water evaporated (kg)

M_2 is the mass of ceramic sample (kg)

Cp,w is the specific heat of water (kJ/kg °C)

Cp,c is the specific heat of ceramic (kJ/kg °C)

Lv is the latent heat of water (kJ/kg)

Using the above method, the theoretical energy needed to evaporate the water in one ceramic casting is about 0.033 kWh. Taking into account the microwave coupling efficiency of 80%, this translates into about 0.041 kWh of energy per ceramic casting. The required microwave unit size can then be calculated as follows:

Microwave Unit Size = Energy Required To Dry One Casting x Throughput

$$= \frac{0.041 \text{ kWh}}{\text{Piece}} \times \frac{5 \text{ Pieces}}{\text{Minute}} \times \frac{60 \text{ Minute}}{\text{Hour}} = 12.3 \text{ kW}$$